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(71) Applicant: MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
Kadoma-shi, Osaka 571-8501 (JP)

(72) Inventors:
- Ono, Hitoshi
Hirakata City, 573 (JP)
- Koudo, Toshikazu
Nishinomiya City, 663 (JP)
- Ayaki, Yasushi
Neyagawa City, 572 (JP)
- Kuno, Yoshiki
Osaka City, 535 (JP)

(74) Representative: Schirdewahn, Jürgen
Jung Schirdewahn Lemke
Clemensstrasse 30
80803 München (DE)

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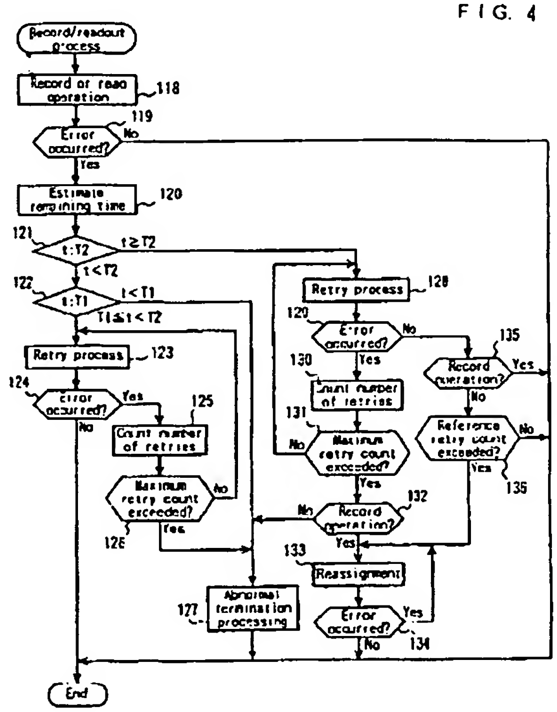
(54) Error recovery processing method and storage apparatus

(57) The present invention is directed to the provision of a storage apparatus using an error recovery processing method suitable for processing moving picture data and the like, wherein a remaining time available for error processing is estimated from the difference between the time required to execute accumulated record or read requests and a limit time, and an error processing method, from among a plurality of error processing methods requiring different lengths of time for processing, is selected and carried out according to the remaining time.

F I G. 4



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates a method for processing error recovery, and a storage apparatus using these methods.

[0002] An example of a storage apparatus that ensures storing each file in contiguous empty areas is disclosed in the gazette of the Japanese unexamined patent application, (TOKKAI) Hei 7-200369. In the storage apparatus of this prior art, file reallocation is performed in which any file located after an empty area is moved forward to fill the empty area, thereby moving the empty area rearward. According to the storage apparatus disclosed in the gazette of the Japanese unexamined patent application, (TOKKAI) Hei 7-200369, it is claimed that, by evaluating the time required for the file reallocation and the size of the resulting contiguous empty areas, effective file reallocation is achieved to secure contiguous empty areas.

[0003] The conventional storage apparatus disclosed in the gazette of the Japanese unexamined patent application, (TOKKAI) Hei 1-236488, which is designed to record data by searching empty area management information for an empty area long enough to record the data, has had the problems that it requires a search time before starting the recording, and also that the method cannot be applied unless the size of the file to be recorded is known in advance.

[0004] Further, the conventional storage apparatus disclosed in the gazette of the Japanese unexamined patent application, (TOKKAI) Hei 7-200369, which is designed to secure contiguous empty areas by performing file reallocation, has had the problem that the time required to evaluate the efficiency of reallocation and to reallocate the files increases as the magnetic disk capacity increases.

[0005] Next, error recovery processing methods employed in the conventional storage apparatus will be described.

[0006] Storage apparatus capable of random accessing, such as magnetic disk and optical disk apparatus, have built-in error recovery functions in order to improve recording or readout reliability. Such error recovery functions include, for example, a retry process in which a record or read operation is retried on an area where an error has occurred, and a reassignment process in which a logical block address previously assigned to an error area is reassigned to another area and data on this is registered in a defective area table to inhibit the use of the error area.

[0007] These error recovery processes, however, have had the problem that they are not suitable for real-time processing since the processing for error recovery takes long time compared to read/write operations, and in the case of the retry process, the completion time of the processing cannot be estimated because the same process is repeated.

[0008] One example of the conventional magnetic disk recording apparatus will be described with reference to FIG. 11. FIG. 11 is a plan view showing in schematic form the configuration of the conventional magnetic disk ; here, the parts identical in configuration and function to those shown in FIG. 23 are designated by the same numerals.

[0009] In FIG. 11, the recording surface of the magnetic disk 182 as a magnetic recording medium is divided into concentric circles, thus forming a plurality of tracks 183 as storage area units. Each track 183 consists of a plurality of sectors 184 each of which is the smallest access unit. The head 188 records data on the magnetic disk 182, or reads out data on the magnetic disk 182. The arm 187 has the function of supporting the head 188 thereon and moving it across the surface of the magnetic disk 182.

[0010] Each sector 184 is assigned a logical block address 185 which is a logical area number. An alternate sector 186 is a sector used in place of tine sector 184 in the event of a failure of the latter. Since each sector 184 has the logical block address 185 as a logical area number, any storage area on the magnetic disk 182 can be identified by the logical block address 185.

[0011] To read data recorded on the magnetic disk 182 having the above-mentioned configuration, first it is determined to which sector on which track the sector 184 holding-the data specified by the logical block address 185 corresponds.

[0012] Next, the head 188 is moved to the track 183 containing the thus determined sector. The head 188 moved to the specified track 183 waits until the specified sector 184 is brought beneath the head 188 by the rotation of the magnetic disk 182, and then reads out the desired data.

[0013] When recording data also, the head 188 is moved to the empty sector 184 specified by the logical block address 185, as in the above-mentioned read operation, and records the data on that sector.

[0014] If an error occurs when recording or reading at the logical block address 185, the recording or reading operation is retried after slightly shifting the position of the head 188. This retry operation is repeated a prescribed number of times until proper recording or reading is done.

[0015] If recording cannot be done on the specified sector 184 after repeating the retry operation, a reassignment operation is performed by first reassigning the logical block address 185 originally assigned to the error sector 184 to the alternate sector 186 and then performing a record operation on the alternate track 186. In the read operation, if the data can be read out after repeating the retry operation the prescribed number of times, a reassignment operation is performed by first copying the data held in the sector 184 to the alternate sector 186 and then reassigning the logical

block address 185 originally assigned to the error sector 184 to the alternate sector 186.

[0016] In the above-mentioned error recovery process, not only a rotational delay occurs while waiting for the head 188 to arrive at the position of the specified sector, but also the head 188 is being moved back and forth. The error recovery thus takes time for processing compared to a normal operation, rendering the method unsuitable for an apparatus that requires high-speed processing such as real-time processing.

[0017] To overcome the above-mentioned problem, there has been proposed a storage apparatus which is disclosed in the gazette of the Japanese unexamined patent application, (TOKKAI) Hei 7-111035. The storage apparatus disclosed in this publication is constructed in such a manner that a single recording area is divided into areas for recording data that requires high reliability and areas for recording data that requires high processing speed rather than reliability, and the error recovery processing method is switched between different modes according to the type of recording area.

[0018] It is proposed that this conventional storage apparatus be used as an apparatus for continuously recording large volumes of data such as video signals, by switching the record/playback operations between a mode that gives priority to data reliability and a mode that omits error recovery operations and gives priority to high-speed processing, according to the position and attribute of the recording areas, for example, management areas and data areas.

[0019] However, in the conventional storage apparatus (Hei 7-111035), since the configuration involves dividing the recording area and changing error processing modes for each recording area, the mode of record/playback operation is selected based on the position and attribute of each recording area, without regard to the present load of the recording/playback apparatus. As a result, when the load of the record/playback operation varies, the mode of record/playback operation is always selected by assuming the heaviest load condition. This has presented a problem in that error recovery is not performed even when the load is light and error recovery can be performed.

[0020] The entire disclosure of the Japanese Patent Applications No. Hei 1-236488, Hei 7-200369 and Hei 7-111035 including specification, claims, drawings and summary are incorporated herein by reference in its entirety.

BRIEF SUMMARY OF THE INVENTION

[0021] To overcome the above-mentioned problems it is an object of the present invention to provide a recording area management method and an error recovery processing method for use with the storage apparatus.

[0022] The present invention provides an error recovery processing method comprising the steps of:

accumulating a plurality of record requests or read requests;
recording data on or reading data from a recording medium in accordance with the accumulated record or read requests;
in the event of a data read error or record error, estimating a remaining time available for error processing from the time required to execute the accumulated record or read requests; and
selecting an error processing method according to the estimated remaining time from among a plurality of error processing methods requiring different lengths of time for error processing, and carrying out the selected error processing method.

[0023] According to the error recovery processing method of the present invention, after accumulating a plurality of record requests or read requests, data is read from or recorded on a recording medium in accordance with the accumulated requests, and if an error occurs in data reading or recording, the remaining time available for error processing is estimated from the time required to execute the accumulated requests, and an error processing method is selected according to the estimated remaining time from a plurality of error processing methods requiring different lengths of time for processing, thereby carrying out necessary error processing without fail in a record/readout process. In this way, according to the error recovery processing method of the present invention, a highly reliable defective area management method can be provided.

[0024] The present invention also provides a storage apparatus in which the error recovery processing method is carried out, comprising:

request accumulating means for accumulating a plurality of record or read requests;
recording/reading means for recording data on or reading data from a recording medium in accordance with the record requests or read requests accumulated in the request accumulating means;
remaining time estimating means for estimating a remaining time available for error processing from the time required to execute the record or read requests accumulated in the request accumulating means; and
error processing carrying out means capable of selectively carrying out an error processing method according to the remaining time estimated in the remaining time estimating means from among a plurality of error processing methods requiring different lengths of time to process a read error or record error occurring in the recording/reading means.

[0025] In this way, since error recovery processing is performed by considering not only the position and attribute of a recording area but also the remaining time estimated from the record requests or read requests and available for error processing, the storage apparatus of the present invention has features combining high reliability with high-speed processing capability.

[0026] While the novel features of the invention are set forth particularly in the appended claims, the invention, both as to organization and content, will be better understood and appreciated, along with other objects and features thereof, from the following detailed description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0027]

FIG. 1 is a block diagram showing in schematic form the configuration of a television receiver using a storage apparatus according to a first embodiment of the present invention;
FIG. 2 is a block diagram showing in schematic form the configuration of the storage apparatus according to the first embodiment;
FIG. 3 is a diagram for explaining one example of a command queue according to the first embodiment;
FIG. 4 is a flow chart illustrating a record/readout process flow according to the first embodiment;
FIG. 5 is a flow chart illustrating a record/readout process flow according to a second embodiment of the present invention;
FIG. 6 is a diagram for explaining one example of a command queue according to the second embodiment;
FIG. 7 is a block diagram showing in schematic form the configuration of a storage apparatus according to a third embodiment of the present invention;
FIG. 8 is a diagram showing one example of a temporary defective area table according to the third embodiment;
FIG. 7 is a flow chart illustrating a reassignment process flow according to the third embodiment;
FIG. 10 is a flow chart illustrating a temporary defective area check process flow according to the third embodiment; and
FIG. 11 is the diagram for explaining the configuration of the magnetic disk in the conventional magnetic disk apparatus.

DETAILED DESCRIPTION OF THE INVENTION

<<Embodiment 3>>

[0028] A first embodiment of the storage apparatus of the present invention will be described below with reference to relevant drawings.

[0029] FIG. 1 is a block diagram showing essential portions of a television receiver using the storage apparatus of the first embodiment.

[0030] In FIG. 1, an analog-digital video signal converter 101a converts an analog video signal, input from a tuner not shown or input via a video input terminal 190, into a digital video signal. An analog-digital audio signal converter 101b converts an analog audio signal, input from the tuner or input via an audio input terminal 191, into a digital audio signal. A video signal processing circuit 2 processes the digital video signal, while an audio signal processing circuit 103 processes the digital audio signal.

[0031] A digital-analog video signal converter 104a converts the digital video signal into an analog video signal, and a digital-analog audio signal converter 104b converts the digital audio signal into an analog audio signal. A video output circuit 105 generates and outputs a signal for displaying an image on a CRT 107. An audio output circuit 106 generates and outputs a signal for producing sound from a speaker 108. A record/playback circuit 109 is a circuit for recording the digital video and audio signals on a magnetic disk apparatus 110, and for reading the digital video and audio signals from the magnetic disk apparatus 110.

[0032] The operation of the thus configured television receiver according to the first embodiment will be described below.

[0033] The analog video signal input via the video input terminal 190 and the analog audio signal input via the audio input terminal 191 are converted by the analog-digital video signal converter 101a and the analog-digital audio signal converter 101b into a digital video signal and a digital audio signal, respectively, and the converted signals are respectively supplied to the video signal processing circuit 102 and the audio signal processing circuit 103.

[0034] The video signal processing circuit 102 first separates the digital video signal into a luminance signal and color-difference signals, and then switches the destination of the luminance signal and color-difference signals between the record/playback circuit 109 and the digital-analog video signal converter 104a. The video signal processing circuit

102 also has the function of directing the luminance signal and color-difference signals, supplied from the record/playback circuit 109, to the digital-analog video signal converter 104a.

[0035] The audio signal processing circuit 103 switches the destination of the digital audio signal between the record/playback circuit 109 and the digital-analog audio signal converter 104b. The audio signal processing circuit 103 also has the function of directing the audio signal, supplied from the record/playback circuit 109, to the digital-analog audio signal converter 104b.

[0036] The digital-analog video signal converter 104a converts the digital luminance signal and color-difference signals into analog signals, which are supplied to the video output circuit 105 to reproduce an image on the CRT 107. The digital-analog audio signal converter 104b converts the digital audio signal to an analog signal, which is supplied to the audio output circuit 106 to reproduce sound from the speaker 108.

[0037] The record/playback circuit 109 records the luminance signal and color-difference signals, supplied from the video signal processing circuit 102, and the audio signal, supplied from the audio signal processing circuit 103, as data onto the magnetic disk apparatus 110. The record/playback circuit 109 also has the function of reading the data recorded on the magnetic disk apparatus 110, and supplying the luminance signal and color-difference signals to the video signal processing circuit 102 and the audio signal to the audio signal processing circuit 103.

[0038] With the above-mentioned operation, a television receiver is realized that can record and play back video and audio on the magnetic disk apparatus 110.

[0039] Next, the operation of the magnetic disk apparatus 110 as the storage apparatus used with the television receiver according to the first embodiment of the present invention, will be described in detail with reference to FIGs. 2, 3, and 4.

[0040] FIG. 2 is a block diagram showing in schematic form the configuration of the storage apparatus according to the first embodiment. In FIG. 2, a command queue 111, using an area within a RAM, temporarily stores and holds a command supplied via an external command interface until the command is executed. A remaining time estimator 112 estimates a remaining time from the time required to execute the commands stored in the command queue 111 and a predetermined limit time. A defective area table 113 stores position data of nonusable areas by using an area within a nonvolatile RAM. A data buffer 114 is a temporary data storage area using a portion of a RAM, and allowing data transfer to and from an external data interface. A record/readout unit 115 transfers data to or from the data buffer 114 in accordance with the command from the command queue 111, and reads out or records data on the magnetic disk apparatus 110. An error processing method selection unit 116 selects an error processing method based on the remaining time estimated by the remaining time estimator 112 when an error occurs in the record/readout unit 115. An error processing unit 117 performs error processing in accordance with the method selected by the error processing method selection unit 116.

[0041] The external command interface and the external data interface are both connected to the record/playback circuit 109, and are used to receive commands from the record/playback circuit 109 and to input and output data.

[0042] FIG. 3 is a diagram showing a specific example of the structure of the command queue 111, wherein reference numerals 137, 138, and 139 indicate specific commands. As shown in FIG. 3, the command queue 111 consists of symbols "read" and "write" designating the operation to be performed, the logical block address of the first sector to be processed, and the number of sectors to be processed.

[0043] FIG. 4 is a flow chart illustrating the flow of a record/readout process according to the first embodiment.

[0044] The retry process and reassignment process to be carried out in the flow chart shown in FIG. 4 will be described.

[0045] The retry process is a method of finding conditions that enable data recording or reading by repeating a record request or a read request while changing physical conditions. Assuming that the maximum number of retries is set to 10, for example, the first and second retry operations are performed using the same operating conditions as the initial conditions, then the third retry operation is performed by shifting the head inward from a reference position by an amount equal to 10% of track spacing. Further, the fourth retry operation is performed by shifting the head outward from the reference position by an amount equal to 10% of track spacing, the fifth retry operation is performed by shifting the head inward from the reference position by an amount equal to 15% of track spacing, and the sixth retry operation is performed by shifting the head outward from the reference position by an amount equal to 15% of track spacing. The seventh retry operation is performed by increasing bias current to the head by one step from a reference value, and the eighth retry operation is performed by reducing bias current to the head by one step from the reference value. The ninth and tenth retry operations are performed by moving the head back to the initial conditions. In this way, in the retry process in the third embodiment, record or read operations are performed by changing the head position and circuit parameters in accordance with a predetermined procedure for each retry operation.

[0046] The reassignment process will be described next.

[0047] A sector as a storage area unit of a magnetic disk is assigned two numbers: a logical block address which is a logical area number that an external control unit uses, and a physical address which is used within the magnetic disk apparatus 110, and which indicates the physical position on the magnetic disk by specifying a particular magnetic disk

among the magnetic disks mounted, the side of the magnetic disk, the track number as counted from the outermost track, and the sector number within that track. In the magnetic disk apparatus 110, the logical block address specified by an external device is translated into a physical address by using a logical block address to physical address translation table contained in the magnetic disk apparatus 110, and based on the physical address, the head is moved to the sector where data is to be recorded or read out.

[0048] The reassignment process uses the above-mentioned head moving process, and translates the logical block address originally assigned to an error area into the physical address of a sector reserved for use as an alternate sector. With this reassignment process, an alteration is made to the translation table so that the logical block address is reassigned to an error-free sector. By performing the reassignment process in this way, the external control unit can access without having to be aware of the logical block address at which an error occurred.

[0049] The record/readout process will be described below with reference to FIG. 4 focusing particularly on the error processing selection operation.

[0050] When a command to record or read data on the magnetic disk is issued to the storage apparatus of the first embodiment, the contents of the command are temporarily stored in the command queue 111, as shown in FIG. 2. The record/readout unit 115 acquires the information of the command stored in the command queue 111, for example, the information of the command 137 (FIG. 3) to initiate the record or read operation.

[0051] In the record/readout process of FIG. 4 the record or read operation is performed in process step 118, and a decision is made in decision step 119 as to whether an error has occurred or not. If it is decided in decision step 119 that no error has occurred, the record/readout process is terminated.

[0052] If it is decided in decision step 119 that an error has occurred, error processing is initiated; first, in process step 120, the time required to execute the commands currently stored in the command queue 111, for example, the commands 137, 138, 139, and 140, is estimated, thereby computing the remaining time t during which reading or writing is not performed.

[0053] Here, an explanation will be given of the method of computing the remaining time t in process step 120 when the commands stored in the command queue 111 are executed.
The remaining time t is computed by the following equation (2). Here, the execution time of each command is approximated by the proportional expression of the amount of data to be recorded or read out. In equation (2), Li is the amount of record or readout data specified by each command stored in the command queue 111, V is the amount of signal recorded or read out in unit time by the record/readout unit 115, and T is the predetermined limit time:

$$t = T-(\Sigma Li)/V \tag{2}$$

[0054] In this equation, Σ indicates the summation of all the commands stored in the command queue 111. For example, consider the case where four commands, 137, 138, 139, and 140, are stored in the command queue 111. When the sector size is 512 bytes, the amount of signal, V, recorded or read out in unit time is 4,000,000 bytes/second, and the limit time T is 200 milliseconds, then the remaining time t is calculated as follows:

$$\begin{aligned} t &= 0.2 - (100 \times 512) \times 4 / 4{,}000{,}000 \\ &= 0.2 - 0.0512 \text{ (sec.)} \\ &= 0.1488 \text{ (sec.)} \quad \ldots (3). \end{aligned}$$

[0055] Returning now to the flow chart of FIG. 4, the error processing in the record/readout process will be described.

[0056] In decision step 121, the remaining time t thus estimated is compared with the error processing time T2 required to carry out an error processing method that takes the longest processing time. If the remaining time t is shorter than the longest error processing time T2, then in decision step 121 the remaining time t is compared with the error processing time T1 required to carry out an error processing method that takes the second longest processing time. If the remaining time t is shorter than the second longest error processing time T1, it is then determined that there is not enough time left for error processing, and the process proceeds to process step 127 to notify the higher-level control unit that the record or read operation has not been completed normally, upon which the process flow is terminated. On the other hand, if the remaining time t is equal to or longer than the error processing time T1, the process proceeds to process step 123 where a record or readout retry operation is performed as error processing.

[0057] The result of the retry operation is checked in decision step 124, and if there are no errors, the process flow is terminated. If an error is detected in decision step 124, the number of retries is counted in process step 125; then, in decision step 126, it is determined whether or not the number of retries thus counted has exceeded a predetermined

maximum retry count. If it is determined in decision step 126 that the present number of retries has yet to exceed the maximum retry count, the process returns to process step 123 to repeat the retry operation. On the other hand if it is determined in decision step 126 that the present number of retries has exceeded the maximum retry count, then it is determined that the error recovery has failed, and the process proceeds to process step 127 to notify the higher-level control unit of an error occurrence, upon which the process flow is terminated.

[0058] On the other hand, if it is determined in decision step 121 that the remaining time t is equal to or longer than the error processing time T2, first in process step 128 a record or readout retry operation is performed as error processing. The result of the retry operation is checked in decision step 129. If an error is detected in decision step 129, the number of retries is counted in process step 130; then, in decision step 131, it is determined whether or not the number of retries thus counted has exceeded the predetermined maximum retry count.

[0059] If it is determined in decision step 131 that the present number of retries has yet to exceed the maximum retry count, the process returns to process step 128 to repeat the retry operation. On the other hand, if it is determined in decision step 131 that the present number of retries has exceeded the maximum retry count, then in step 132 it is determined whether the commanded operation is a record operation or a read operation. If the commanded operation is a read operation, it is determined that the reading is impossible and the higher-level control unit is notified accordingly. If the commanded operation is a record operation, the process proceeds to process step 133 where a reassignment operation is performed to reassign the logical block address of the error sector to another sector.

[0060] In decision step 134, it is determined if there has occurred an error in the reassignment operation performed in process step 133; if an error is detected, process step 133 is repeated, but if no errors, the process flow is terminated.

[0061] If, in decision step 129, it is determined that there are no errors, then in decision step 135 it is determined whether the commanded operation is a record operation or a read operation. If it is determined in decision step 135 that the commanded operation is a record operation, the process flow is terminated. On the other hand, if the commanded operation is a read operation, then in decision step 136 it is determined whether or not the number of retries has exceeded a predetermined reference retry count. If the present number of retries has yet to exceed the reference retry count, the process flow is terminated without further processing. If the present number of retries has exceeded the reference retry count, a reassignment operation is performed in process step 133 to prevent the data from becoming unretrievable in case the sector is rendered unreadable in future. The process flow after this reassignment operation is the same as that of the record operation earlier mentioned.

[0062] An explanation will now be given of the values of the error processing times T1 and T2 used in the decision steps 121 and 122 in the error processing flow shown in FIG. 4.

[0063] The conditions used in the error processing are as follows: the time required for one retry of a command is 10 milliseconds, the time required for the reassignment operation is 50 milliseconds, and the maximum number of retries before the retry operation is aborted is set to 10.

[0064] The error processing time T1 serves as a criterion for determining whether only a retry operation is to be performed as error processing or nothing is to be performed. Accordingly, the error processing time T1 is the time required to repeat the retry operation the maximum number of times, and is given as follows:

$$\begin{aligned} T1 &= (\text{Retry time}) \times 10 \\ &= 10\ \text{msec.} \times 10 \\ &= 100\ \text{msec.} \quad \ldots (4). \end{aligned}$$

[0065] The error processing time T2 serves as a criterion for determining whether a retry operation and a reassignment operation are to be performed as error processing. The error processing time T2 required to perform the retry operation and reassignment operation is given as follows:

$$T2 = (\text{Retry time}) \times 10 + (\text{Reassignment execution time})$$
$$= 10 \text{ msec.} \times 10 + 50 \text{ msec.}$$
$$= 150 \text{ msec.} \quad \ldots (5).$$

[0066] In the case previously shown in FIG. 3 where the four commands 137, 138, 139, and 140 are stored in the command queue, the remaining time t was calculated as 148.8 milliseconds as shown in equation (3). In this case, therefore, an error processing method that performs only a retry operation is selected.

[0067] In this way, by selecting the appropriate error processing method according to the remaining time t representing the difference between the time required to execute the commands and the limit time, the time required for error processing in the event of an error occurrence can be limited, thus reducing the delay caused in the record/readout process by the error processing.

[0068] The first embodiment has been described by taking an example in which the retry operation and reassignment operation are used as the error processing methods and three choices, "no error processing", "retry operation only", and "retry operation and reassignment operation", are presented for selection. The present invention, however, is not limited to the error processing methods and the number of choices shown in the third embodiment, but it will be appreciated that the same effect as achieved by the first embodiment can be obtained as long as provisions are made to select an appropriate error processing method according to the remaining time t.

[0069] In the first embodiment, the command queue has been described as having the structure consisting of the command operation, the logical block address of the first sector, and the number of sectors, but the command queue in the storage apparatus of the present invention is not limited to the structure illustrated in the first embodiment; rather, the command queue can be configured in any suitable structure as long as it represents the contents of processing.

[0070] Further, in the present invention, the calculation method for the remaining time t is not limited to the equation used in the description of the first embodiment, but any other method that can estimate the difference between the limit time and the command execution time may be used.

[0071] In the first embodiment, the defective area table has been implemented using a portion of a nonvolatile RAM, but instead, the defective area table may be recorded on a disk, for example; that is, any storage device that can retain data when power is cut off may be used.

[0072] Furthermore, the first embodiment has been described using a magnetic disk apparatus as an example of the storage apparatus, but the present invention is applicable for any storage apparatus capable of random accessing, including, for example, a magneto-optical disk storage apparatus.

<<Embodiment 2>>

[0073] Next, a second embodiment of the storage apparatus of the present invention will be described with reference to the accompanying drawings.

[0074] FIG. 5 is a flow chart illustrating an error processing flow in a record/readout process according to the storage apparatus of the second embodiment. FIG. 6 is a diagram showing an example of a command queue structure according to the second embodiment.

[0075] In the command queue structure shown in FIG. 6 commands 146, 147, 148, and 149 are specific examples of commands, each command consisting of a symbol designating a "read" or "write" operation, the logical block address of the first sector to be processed, the number of sectors to be processed, and an error processing level.

[0076] In the flow chart of FIG. 5 as in the foregoing third embodiment, when a command to record or read data is issued to the storage apparatus of the second embodiment, the record/readout process is invoked, and in process step 118, the data record or read operation is performed. In decision step 119, it is determined whether or not an error has occurred, and if no errors, the record/readout process is terminated. On the other hand, if there is an error, error processing is initiated; first, in process step 141, the time required to execute the commands currently stored in the command queue 111, for example, the commands 146, 147, 148, and 149, is estimated, thereby computing the remaining time t during which reading or writing is not performed.

[0077] Here, an explanation will be given of the method of estimating the remaining time t in process step 141 when the commands stored in the command queue 111 are executed.

[0078] When Li is the amount of record or readout data specified by each command stored in the command queue 111, V is the amount of signal recorded or read out in unit time by the record/readout unit 115, Tmi is the time required for the head to move between the areas to be recorded or read by the commands, and T is the predetermined limit time, then the remaining time t is computed by the following equation (6):

$$t = T-(\Sigma Li)/V-\Sigma Tmi \quad (6).$$

[0079] In equation (6), Σ indicates the summation of all the commands stored in the command queue 111. For example, consider the case where four commands, 146, 147, 148, and 149, are stored in the command queue 111. When the sector size is 512 bytes, the amount of signal, V, recorded or read out in unit time is 4,000,000 bytes/second, the head moving time Tmi is 15 milliseconds regardless of the area position, and the limit time T is 200 milliseconds, then the remaining time t is calculated as follows:

$$\begin{aligned} t &= 0.2 - (100 \times 512) \times 4 / 4{,}000{,}000 - 0.015 \times 4 \\ &= 0.2 - 0.0512 - 0.06 \\ &= 0.0888 \text{ (sec.)} \quad \ldots (7). \end{aligned}$$

[0080] Returning now to the flow chart of FIG. 5 the error processing in the record/readout process will be described.

[0081] In decision step 142, the error processing subsequently performed is selected based on the value of the error processing level assigned to the issued command.

[0082] If the error processing level of the command is 1, the retry operation and reassignment operation from process step 128 through decision step 136 are carried out. The processing of the retry operation and reassignment operation from process step 128 through decision step 136 is the same as the processing from process step 128 through decision step 136 shown in FIG. 4 in the foregoing, first embodiment, and the description thereof will not be repeated here.

[0083] If the error processing level of the command is 2, then in decision step 143 the estimated remaining time t is compared with the time T2 required to carry out an error processing method that takes the longest time for error processing. If the remaining time t is equal to or longer than the error processing time T2, the retry operation and reassignment operation from process step 128 through decision step 136 are carried out. On the other hand, if the remaining time t is shorter than the error processing time T2, only the retry operation from process step 123 through decision step 127 is carried out. The processing of the retry operation from process step 123 through decision step 127 is the same as the corresponding processing in the foregoing first embodiment, and the description thereof will not be repeated here.

[0084] If the error processing level of the command is 3, then in decision step 144 the estimated remaining time t is compared with the time T2 required to carry out an error processing method that takes the longest processing time. If the remaining time t is equal to or longer than the error processing time T2, the retry operation and reassignment operation from process step 128 through decision step 136 are carried out. On the other hand, if the remaining time t is shorter than the error processing time T2, then in decision step 145 the estimated remaining time t is compared with the time T1 required to carry out an error processing method that takes the second longest processing time. If the remaining time t is shorter than the time T1, the process proceeds to process step 127 to notify the higher-level control unit that the record or read operation has not been completed normally, upon 1 which the process flow is terminated.

[0085] If, in step 145, the remaining time t is equal to or longer than the error processing time T1, only the retry operation from process step 123 through decision step 127 is carried out.

[0086] As mentioned above, a necessary error processing level is preassigned to each command, and if there is not enough remaining time t available for error processing, error processing corresponding to the preassigned error processing level is carried out. If there is enough remaining time t, error processing that requires a longer processing time is carried out; in this way, the performance and processing speed requirements which differ depending on data attributes can be addressed appropriately. Moreover, when there is enough time available for error processing, it is possible to dynamically switch to a higher error processing level that takes a longer processing time but can provide higher reliability than the preassigned error processing level.

[0087] In this way, according to the error recovery processing method in the second embodiment, a plurality of error processing methods are provided from among which, by considering the operation prespecified for each record request or read request, all or part of the plurality of error processing methods are selected and carried out according to the estimated remaining time; this assures minimum reliability required of the data to be recorded or read out, and contributes to further enhancing reliability within a range that does not cause a delay in the processing of the record or read request.

<<Embodiment 3>>

[0088] Next, a third embodiment of the storage apparatus of the present invention will be described with reference to FIGs .7 to 10.

[0089] FIG. 7 is a block diagram showing in schematic form the configuration of the storage apparatus according to the third embodiment in which an error recovery processing method is used.

[0090] In FIG. 7, a command queue 150 temporarily stores a command supplied via an external command interface. A remaining time estimator 151 estimates a remaining time from the time required to execute the commands stored in the command queue 150 and a predetermined limit time. A data buffer 152 has the function of temporarily storing data in order to allow data transfer to and from an external data interface. A record/readout unit 153 reads or records data on a recording medium in accordance with the command from the command queue 150. A defective area table 155 stores position data of nonusable areas.

[0091] A temporary defective area table 157 temporarily stores data associated with an area where an error has occurred during recording or reading. A reassignment processing unit 156, when an error has occurred in the record/readout unit 153, transfers data recorded or to be recorded in the error area to another area for recording therein, and registers the error area in the temporary defective area table 157. A temporary defective area check unit 154 carries out a check, if the remaining time estimated by the remaining time estimator 151 provides enough time to check whether the area registered in the temporary defective area table 157 is a nonusable area or not. If it is determined by the temporary defective area check unit 154 that the area is a nonusable area, then the data associated with that area is recorded in the defective area table 155; if it is determined that the area is usable, the data associated with that area is deleted from the temporary defective area table 157.

[0092] The operation of the storage apparatus shown in FIG. 7 will be described below.

[0093] The command stored in the command queue 150 is read out by the record/readout unit 153, and if the command- thus read out is a record command, the data held in the data buffer 152 is recorded on the disk. On the other hand, if the command stored in the command queue 150 is a read command, data is read out from the disk and stored in the data buffer 152. If an error has occurred during recording or reading, the record/readout unit 153 immediately activates the reassignment processing unit 156 to initiate reassignment processing.

[0094] The reassignment processing unit 156 records data associated with the error sector in the temporary defective area table 157, performs a reassignment operation to allow data to be recorded on an alternate sector, and then instructs the record/readout unit 153 to continue the processing of the command. When the processing of the command is completed, the record/readout unit 153 activates the temporary defective area check unit 154. The temporary defective area check unit 154 acquires the remaining time estimated by the remaining time estimator 151, and determines whether the remaining time provides enough time to perform a temporary defective area check. After this determination, the sector registered in the temporary defective area table 157 is checked to determine whether it is a nonusable sector or not. If the sector is nonusable, then the sector is registered in the defective area table 155. On the other hand, if the sector registered in the temporary defective area table 157 is usable, the sector data reassigned to the alternate area is copied to the sector that has been judged to be usable, and the logical block address is reassigned once again.

[0095] FIG. 8 is a diagram showing an example of the structure of the temporary defective area table 157. In FIG. 8 data 161 is an example showing an area where an error has occurred, and consists of the logical block address already assigned at the time of error occurrence and the physical address designating its physical position on the disk. In the third embodiment, the structure of the temporary defective area table 157 is described as consisting of the logical block address and physical address, but it will be noted that the present invention is not limited to these specific addresses. Rather, in the present invention, any structure may be employed as long as it contains data that can identify the position of the area and data that can identify the logical position applicable before the reassignment, and the present invention is, under any circumstances, not limited to the structure of the fifth embodiment.

[0096] FIG. 9 is a flow chart illustrating the reassignment process flow used in the error recovery processing method according to the third embodiment. The reassignment process flow in the third embodiment will be described below with reference to FIG. 9.

[0097] When an error occurs in the record/readout unit 153 (FIG. 7), the reassignment process is invoked, and in process step 158, the logical block address and physical address of the sector where the error is detected are recorded in the temporary defective area table 157. After the logical block address and physical address have been recorded in the temporary defective area table 157, in process step 159 the logical block address originally assigned to the error sector is reassigned to an unused alternate sector previously reserved as an area for reassignment.

[0098] In process step 160, data is recorded on the alternate sector with the new logical block address.

[0099] In decision step 161, it is determined whether an error has occurred in the recording on the alternate sector; if no errors, the reassignment process is terminated. If an error is detected, then the number of retries for recording is counted in process step 162. Next, if, in decision step 163 the present number of retries is smaller than a predetermined maximum retry count, the recording operation is carried out once again. If the present number of retries has exceeded

the maximum retry count, the process returns to process step 158, and reassignment is carried out to another alternate sector.

[0100] Next, the flow of the temporary defective area check process in the fifth embodiment will be described in detail with reference to FIG. 10. FIG. 10 is a flow chart illustrating the flow of the temporary defective area check process used in the error recovery processing method according to the third embodiment.

[0101] When the temporary defective area check process is invoked, the temporary defective area table 157 (FIG. 8) is checked in decision step 164 to see whether the data associated with the area where the error is detected is recorded or not. If the data associated with the error: area is not recorded in the temporary, defective area table 157, the temporary defective area check process is terminated. On the other hand, if the data associated with the error area is recorded in the temporary defective area table 157, then in process step 165 the time required to process the commands stored in the command queue 150 is estimated, based on which the remaining time t during which recording or reading is not performed is computed.

[0102] In decision step 166, the thus computed remaining time t is compared with the time T required for checking. If the remaining time t is shorter than the check time T, it is determined that there is not enough time to carry out the temporary defective area check process, and the temporary defective area check process is terminated. If the remaining time t is equal to or longer than the check time T, then in process step 167 the data associated with the error area, for example, the data 161 shown in FIG. 8, is acquired from the temporary defective area table 157.

[0103] In process step 168, test data is recorded in the error area acquired from the temporary defective area table 157, for example, at physical address 010040021. In decision step 169, it is checked whether an error has occurred in the test data. If no error is detected in the occurred in the test data. If no error is detected in the test data, the recorded data is read out in process step 170. After confirming in decision step 171 that no error has occurred in reading, the recorded test data is compared in process step 172 with the readout test data.

[0104] In decision step 173, it is determined whether the recorded test data matches the readout test data. If they match, the reassignment is cancelled in process step 174, and the data that has been recorded on an alternate sector assigned the logical block address 5000, for example, is copied to the physical address 010040021, Then, after assigning the logical block address 5000 to the physical address 010040021, the data recorded on the alternate sector is deleted from the temporary defective area table 157 in process step 175, and the process returns to decision step 164.

[0105] If, in decision step 173, the recorded test data does not match the readout test data, the data associated with the error area is recorded in the defective area table 155 in process step 178, and the process proceeds to process step 175.

[0106] If, in decision step 169, an error is detected in the test data, the number of retries is counted in process step 179. In decision step 180, it is determined whether or not the present count has exceeded the predetermined maximum retry count. If the present count has yet to exceed the maximum retry count, the process returns to process step 168 to perform test data recording. If the present count has exceeded the maximum retry count, then in process step 178 the data associated with the error area is recorded in the defective area table 155.

[0107] If, in decision step 171, an error is detected in reading, the number of retries is counted in process step 176. In decision step 177, it is determined whether or not the predetermined maximum retry count is exceeded; if not exceeded, the process returns to process step 170 to read the test data. If it is determined in decision step 177 that the present count has exceeded the maximum retry count, then in process step 178 the data associated with the error area is recorded in the defective area table 155.

[0108] In this way, according to the error recovery processing method in the third embodiment, an area where an error has occurred is temporarily registered as a defective area in the temporary defective area table for reassignment processing, thus allowing the record/readout process to continue. This serves to reduce the error processing time while maintaining reliability.

[0109] Furthermore, according to the error recovery processing method in the third embodiment, the area registered in the temporary defective area table is checked to determine whether the area has failed in recording or reading for some reason related to the area itself or because of a temporary factor such as a displacement in head position or timing when recording or reading was performed. This serves to prevent defective areas from increasing in number because of such temporary factors.

[0110] Further, according to the error recovery processing method in the third embodiment, the time required to process the commands stored in the command queue is estimated, and when the remaining time t computed based on the estimated processing time is longer than the time required for checking, a check is performed on the area registered in the temporary defective area table. Accordingly, the storage apparatus equipped with the error recovery processing method of the fifth embodiment has an error processing function capable of reducing the delay caused in the record/readout process by the checking operation, thereby allowing realtime operation.

[0111] Although the present invention has been described in terms of the presently preferred embodiments, it is to be understood that such disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art to which the present invention pertains, after having read the above-

mentioned disclosure. Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the scope of the invention.

Claims

1. An error recovery processing method comprising the steps of:

   accumulating (111) a plurality of record requests or read requests;
   recording (115) data an or reading data from a recording medium in accordance with said accumulated record or read requests:
   estimating (112), in the event of a data read error or record error, a remaining time available for error processing from the time required to execute said accumulated record or read requests; and
   selecting (116, 117) an error processing method according to said estimated remaining time from among a plurality of error processing methods requiring different lengths of time for error processing, and carrying out said selected error processing method. (FIG. 2)

2. An error recovery processing method comprising the steps of:

   accumulating (111) a plurality of record requests or read requests;
   recording (115) data on or reading data from a recording medium in accordance with said accumulated record or read requests;
   estimating (112), in the event of a data read error or record error, a remaining time available for error processing from the time required to execute said accumulated record or read requests; and
   selecting (116, 117), from among a plurality of error processing methods requiring different lengths of time for error processing, all or part of said plurality of error processing methods according to said estimated remaining time while considering a mode of operation prespecified for each record or read request, and carrying out said selected error processing method or methods. (FIG. 2)

3. An error recovery processing method according to claim 1, including an error processing method in which position data of an area where said error has occurred is recorded in a first defective area table (157), and after performing a reassignment operation (156) to transfer data recorded or to be recorded in said error area to another area for recording therein, a check (154) is carried out to determine whether or not the area whose position data has been recorded in said first defective area table is a nonusable area, as a result of which if it is determined that said area is nonusable, the position data of said area is recorded in a second defective area table (155), but if it is determined that said area is usable, the position data of said area is deleted from said first defective area table and said area is thus made usable. (FIG. 7)

4. An error recovery processing method according to claim 2, including an error processing method in which position data of an area where said error has occurred is recorded in a first defective area table (157), and after performing a reassignment operation (156) to transfer data recorded or to be recorded in said error area to another area for recording therein, a check (154) is carried out to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, as a result of which if it is determined that said area is nonusable, the position data of said area is recorded in a second defective area table (155), but if it is determined that said area is usable, the position data of said area is deleted from said first defective area table (157) and said area is thus made usable thereafter. (FIG. 7)

5. An error recovery processing method according to claim 3, wherein the remaining time available for performing the check to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, is estimated (151) from the time required to execute said record or read requests, and if said remaining time provides enough time to perform the check, said check (154) is carried out. (FIG. 7)

6. An error recovery processing method according to claim 4, wherein the remaining time available for performing the check to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, is estimated (151) from the time required to execute said record or read requests, and if said remaining time provides enough time to perform the check, said check (154) is carried out. (FIG. 7)

7. A storage apparatus comprising:

request accumulating means (111) for accumulating a plurality of record or read requests;
recording/reading means (115) for recording data on or reading data from a recording medium in accordance with the record or read requests accumulated in said request accumulating means (111);
remaining time estimating means (112) for estimating a remaining time available for error processing from the time required to execute the record or read requests accumulated in said request accumulating means (111); and
error processing carrying out means (116, 117) capable of selectively carrying out an error processing method according to the remaining time estimated in said remaining time estimating means (112) from among a plurality of error processing methods requiring different lengths of time to process a read error or record error occurring in said recording/reading means (115). (FIG. 2)

8. A storage apparatus comprising:

request accumulating means (111) for accumulating a plurality of record requests or read requests;
recording/reading means (115) for recording data an or reading data from a recording medium in accordance with the record or read requests accumulated in said request accumulating means (111);
remaining time estimating means (112) for estimating a remaining time available for error processing from the time required to execute the record or read requests accumulated in said request accumulating means (111);
error processing carrying out means (117) capable of selectively carrying out a plurality of error processing methods requiring different lengths of time to process a read error or record error occurring in said recording/reading means; and
error processing method selection means (116) for selecting an error processing method for each record request or read request according to the remaining time estimated in said remaining time estimating means (112) from among said plurality of error processing methods capable of being carried out by said error processing carrying out means. (FIG. 2)

9. A storage apparatus according to claim 17, further comprising: defective area recording means having a first defective area table (157) and second defective area table (155) for recording position data of defective areas; and defective area discriminating means (154), and wherein:

position data of an area where an error has occurred in recording or reading is recorded in said first defective area table (157), and after performing a reassignment operation to transfer data recorded or to be recorded in said error area to another area for recording therein, a check is carried out by said defective area discriminating means (154) to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, as a result of which if it is determined that said area is nonusable, the position data of said area is recorded in said second defective area table (155), but if it is determined that said area is usable, the position data of said area is deleted from said first defective area table (157) and said area is thus made usable. (FIG. 7)

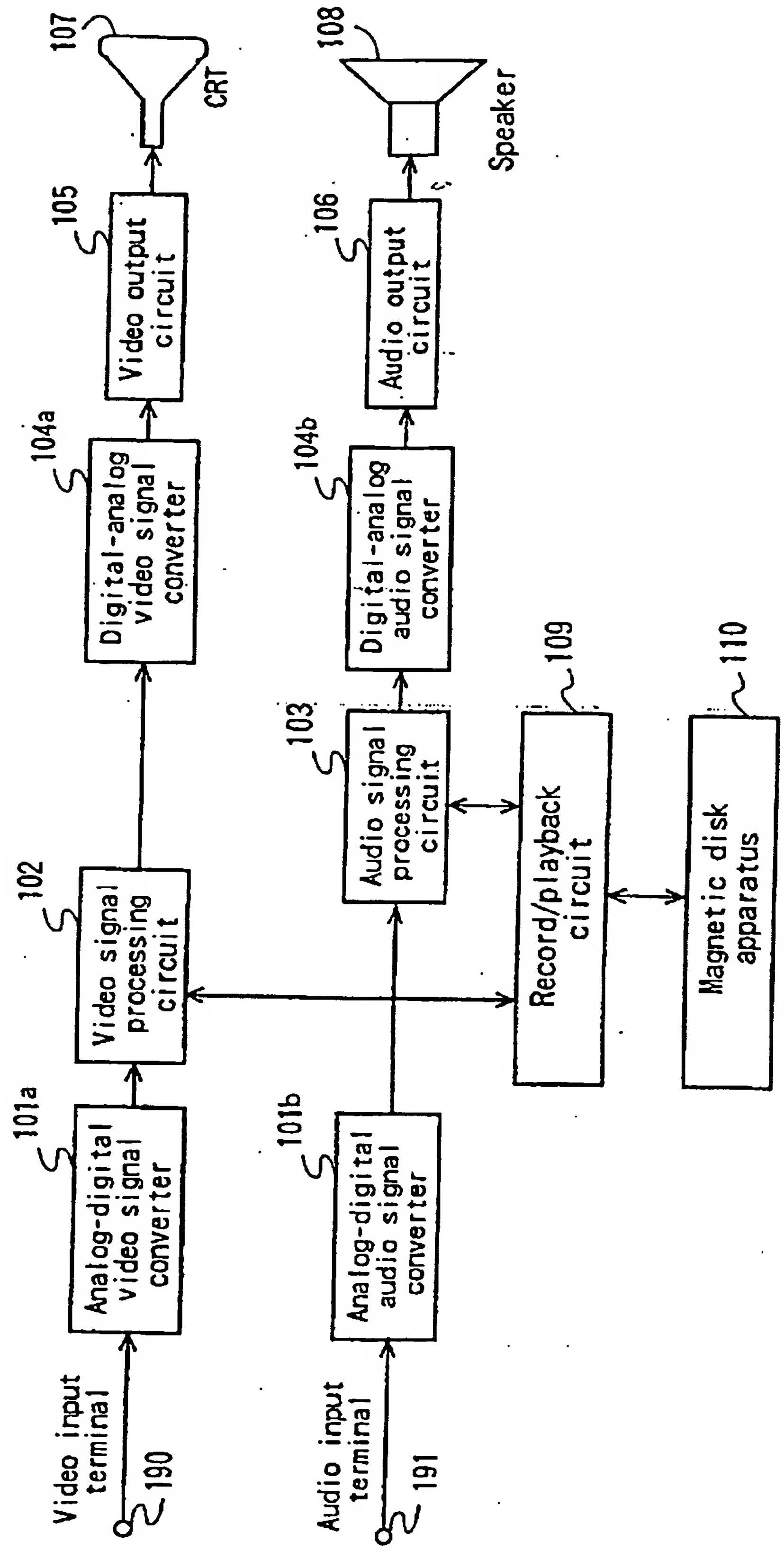
10. A storage apparatus according to claim 18, further-comprising: defective area recording means having a first defective area table (157) and second defective area table (155) for recording position data of defective areas; and defective area discriminating means (154), and wherein:

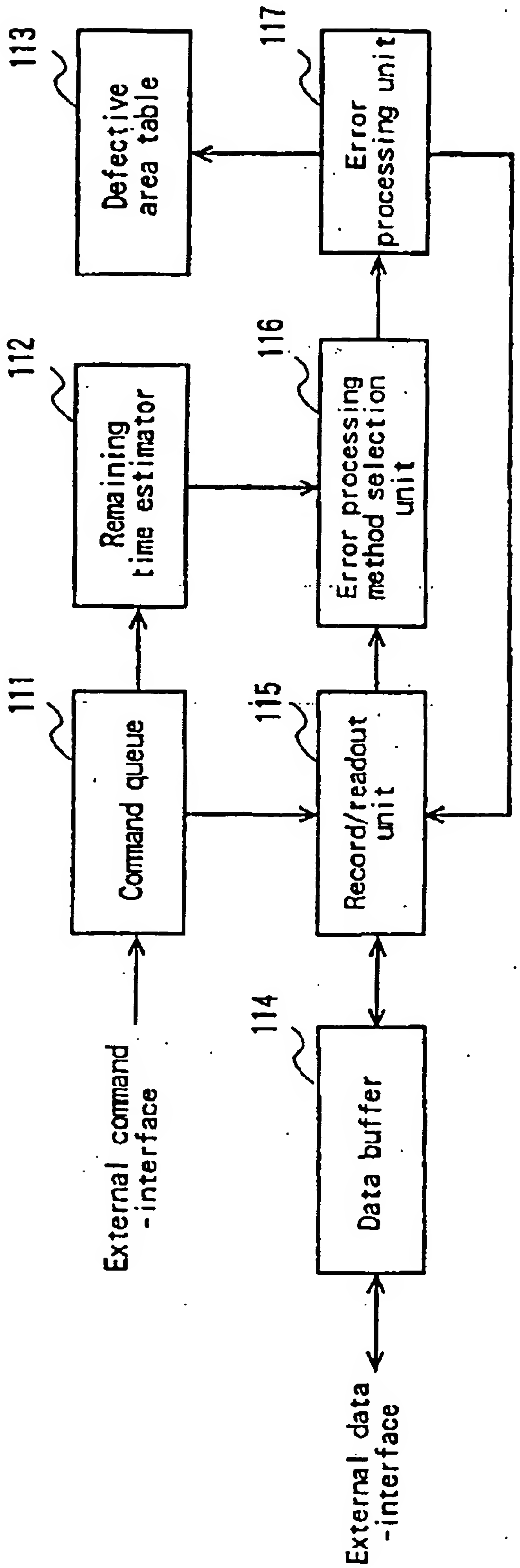
position data of an area where an error has occurred in recording or reading is recorded in said first defective area table (157), and after performing a reassignment operation to transfer data recorded or to be recorded in said error area to another area for recording therein, a check is carried out by said defective area discriminating means (154) to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, as a result of which if it is determined that said area is nonusable, the position data of said area is recorded in said second defective area table (155), but if it is determined that said area is usable, the position data of said area is deleted from said first defective area table (157) and said area is thus made usable. (FIG. 7)

11. A storage apparatus according to claim 9, wherein, an the basis of the time required to execute said record or read requests, said remaining time estimating means (151) estimates the remaining time available for performing the check to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, and if said remaining time provides enough time to perform the check, said check is carried out. (FIG. 2)

12. A storage apparatus according to claim 10, wherein, an the basis of the time required to execute said record or read requests, said remaining time estimating means (151) estimates the remaining time available for performing the check to determine whether or not the area whose position data has been recorded in said first defective area table (157) is a nonusable area, and if said remaining time provides enough time to perform the check, said check is carried out. (FIG. 7)

F I G. 1


Video input terminal
190
Analog-digital video signal converter
101a
Video signal processing circuit
102
Digital-analog video signal converter
104a
Video output circuit
105
CRT
107
Audio input terminal
191
Analog-digital audio signal converter
101b
Audio signal processing circuit
103
Digital-analog audio signal converter
104b
Audio output circuit
106
Speaker
108
Record/playback circuit
109
Magnetic disk apparatus
110



External command -interface
111
Command queue
112
Remaining time estimator
113
Defective area table
114
Data buffer
115
Record/readout unit
116
Error processing method selection unit
117
Error processing unit
External data -interface

F I G. 2

FIG. 3

	Operation	First sector	Number of sector
137	read	10000	100
138	write	220000	100
139	read	30100	100
140	write	421000	100

F I G. 4

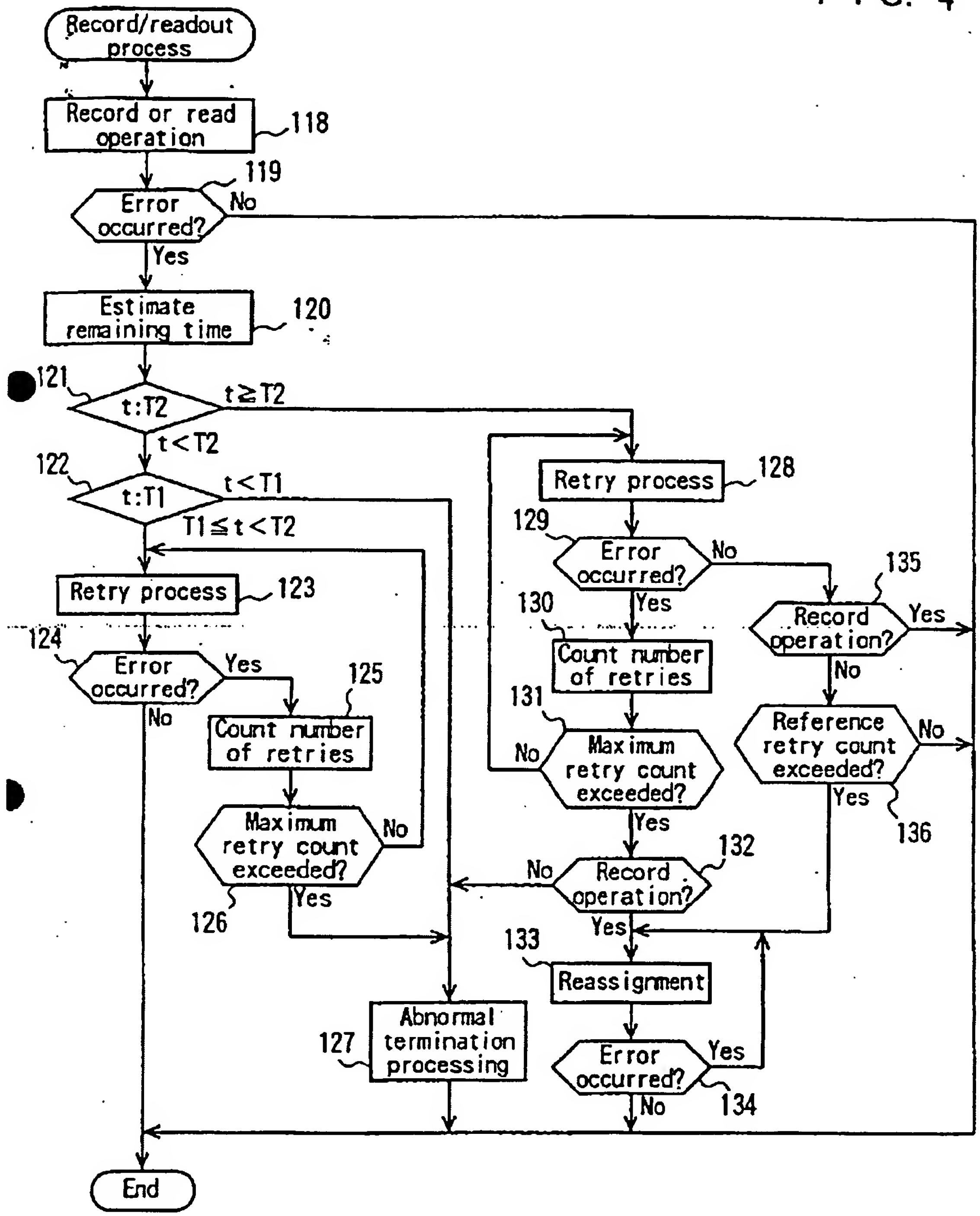

Record/readout process
Record or read operation
118
119
Error occurred?
No
Yes
Estimate remaining time
120
121
t:T2
t≧T2
t<T2
122
t:T1
t<T1
T1≦t<T2
Retry process
123
124
Error occurred?
Yes
No
125
Count number of retries
Maximum retry count exceeded?
No
Yes
126
Abnormal termination processing
127
Retry process
128
129
Error occurred?
No
Yes
130
Count number of retries
131
Maximum retry count exceeded?
No
Yes
132
Record operation?
No
Yes
133
Reassignment
Error occurred?
Yes
No
134
135
Record operation?
Yes
No
Reference retry count exceeded?
No
Yes
136
End

FIG. 5

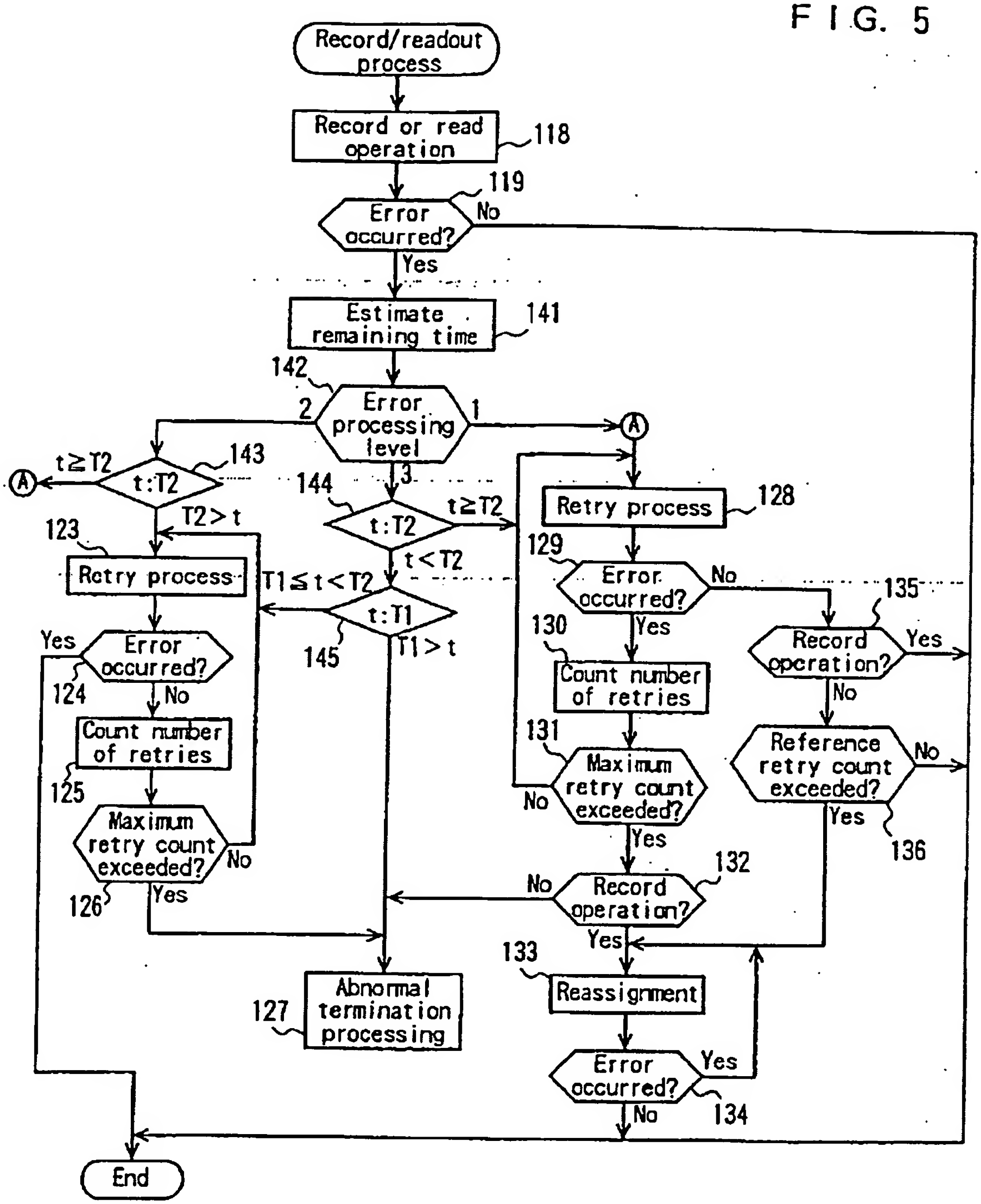
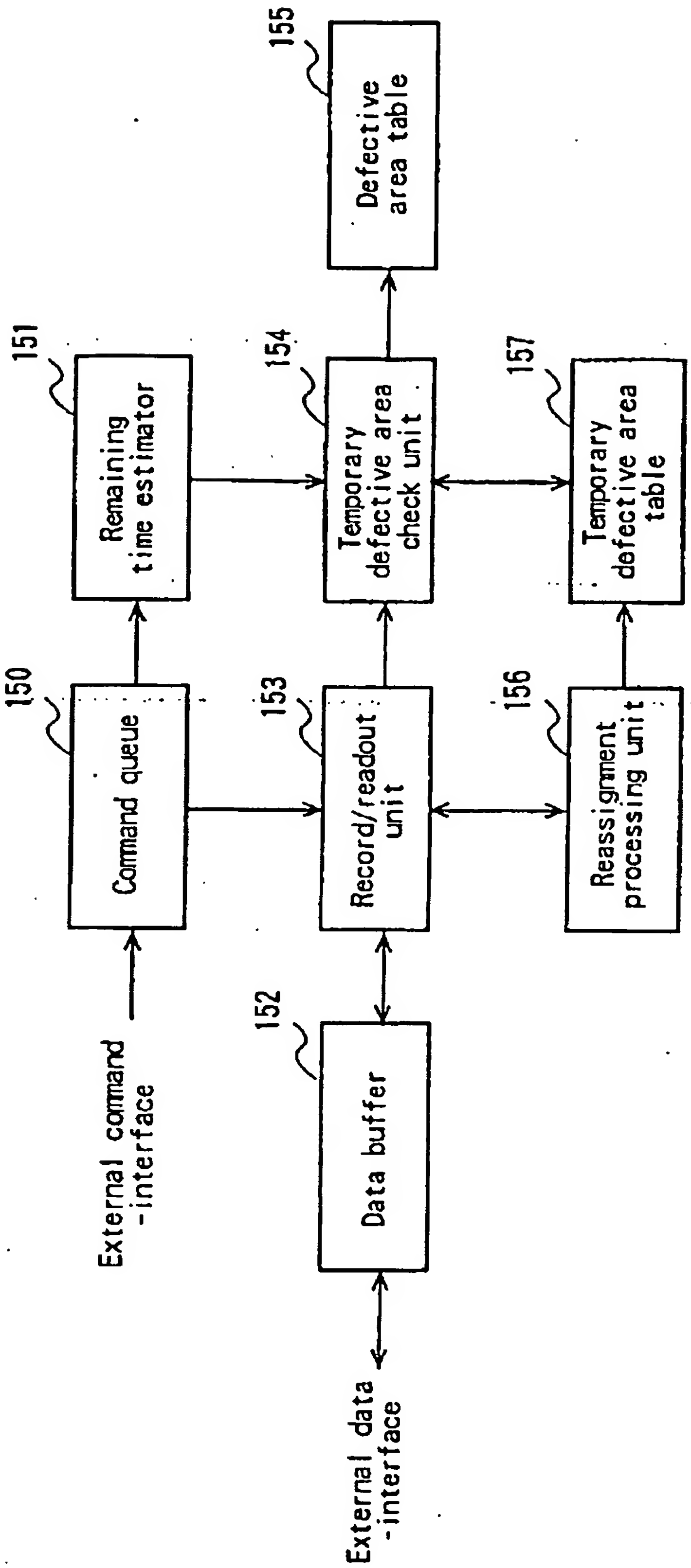

Record/readout process
Record or read operation
118
119
Error occurred?
No
Yes
Estimate remaining time
141
142
Error processing level
2
1
3
A
t≧T2
143
t:T2
144
t:T2
t≧T2
T2>t
123
Retry process
T1≦t<T2
t<T2
t:T1
145
T1>t
Yes
Error occurred?
124
No
Count number of retries
125
Maximum retry count exceeded?
No
126
Yes
Abnormal termination processing
127
Retry process
128
129
Error occurred?
No
135
130
Yes
Count number of retries
Record operation?
Yes
No
131
Maximum retry count exceeded?
No
Reference retry count exceeded?
No
Yes
136
Yes
132
No
Record operation?
Yes
133
Reassignment
Error occurred?
Yes
134
No
End

FIG. 6

	Operation	First sector	Number of sector	Error processing level
146	read	10000	100	3
147	write	220000	100	2
148	read	30100	100	3
149	write	421000	100	2

F I G. 7


External command -interface
Command queue
150
Remaining time estimator
151
External data -interface
Data buffer
152
Record/readout unit
153
Temporary defective area check unit
154
Defective area table
155
Reassignment processing unit
156
Temporary defective area table
157

F I G. 8

	Logical block address	Physical address
161	5000	010040021

FIG. 9

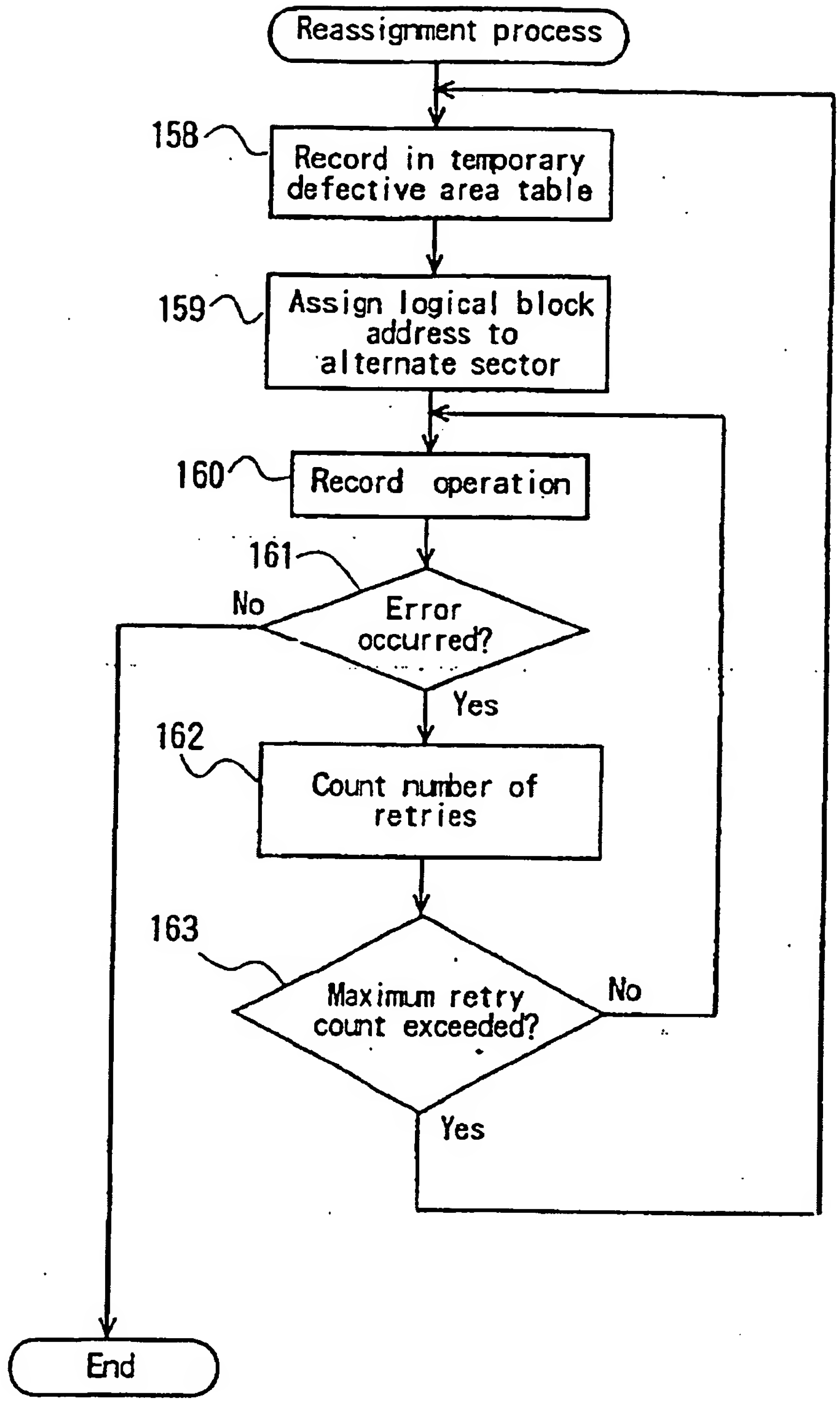
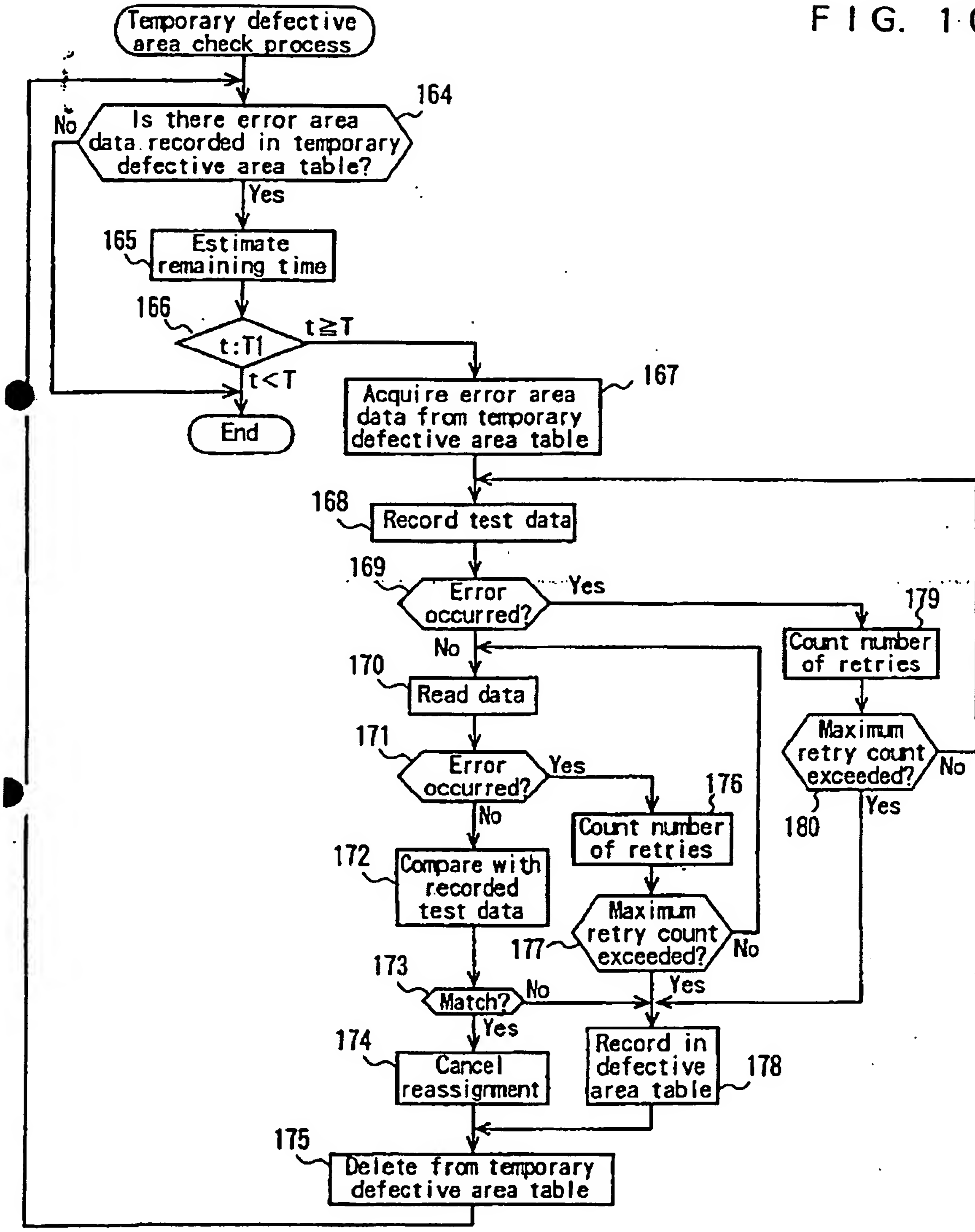

Reassignment process
158
Record in temporary defective area table
159
Assign logical block address to alternate sector
160
Record operation
161
Error occurred?
No
Yes
162
Count number of retries
163
Maximum retry count exceeded?
No
Yes
End

FIG. 10



Temporary defective area check process
164
Is there error area data recorded in temporary defective area table?
No
Yes
165
Estimate remaining time
166
t:T1
t≧T
t<T
End
167
Acquire error area data from temporary defective area table
168
Record test data
169
Error occurred?
Yes
No
179
Count number of retries
170
Read data
Maximum retry count exceeded?
No
Yes
180
171
Error occurred?
Yes
No
176
Count number of retries
172
Compare with recorded test data
177
Maximum retry count exceeded?
No
Yes
173
Match?
No
Yes
174
Cancel reassignment
Record in defective area table
178
175
Delete from temporary defective area table

F I G. 1 1 PRIOR ART